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The use of VR technologies to enhance methods for lighting design practice

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Contemporary architecture, engineering and construction practices primarily use virtual reality (VR) either as a means for communication between the different disciplines, co-design, or as a presentation medium, that gives to clients a human-scale experience of a project. This situation also applies to the field of lighting design, creating a situation where the only area of the lighting design process not influenced by VR, is the area of the design itself. Ideally, lighting is designed within the context of a physical space, allowing a more accurate rendition and perception of how light influences its surroundings and the ability to convey the effects of spatial lighting similar to how humans would perceive them. However, such an approach to visually representing light in the earlier stages of the design is not currently possible. This paper presents a description of the development and testing of an immersive VR tool for the development of lighting design at a 1:1 scale in a real-time virtual environment (VE). While the project's results are limited due to its proof-of-concept development stage, the responses from the participants indicate that the tool is advantageous in the design development as well as the design communication phases. The VR tool described allowed for more design iterations and experiments, better perception of spatial lighting effects, better representation of lighting at a 1:1 scale from a human perceptual perspective, and allows the lighting designer an opportunity to become an actor in the space rather than an observer behind a screen.

Keywords: *Virtual reality, Lighting Design, Design Process, Design Tool*

INTRODUCTION

Contemporary architecture, engineering and construction practices primarily use virtual reality (VR) either as a means for communication between the different disciplines, co-design, or as a presentation medium, that gives to clients a human-scale experience of a project. This situation also applies to the field of lighting design, creating a situation where the only area of the lighting design process not influenced by VR, is the area of the design itself. Ideally, lighting is designed within the context of a physical space, allowing a more accurate rendition and perception of how light influences its surroundings and the ability to convey the effects of spatial lighting similar to how humans would perceive them. However, such an approach to visually representing light in the earlier stages of the design is not currently possible. The authors have therefore attempted to develop such a tool.

To establish a set of criteria for a virtual reality system aiming at improving the process of designing with light for architectural spaces, the paper looks at how the current lighting design process is composed and how the process is applied in a practical framework. A theory of lighting design process proposed by Hansen and Mullins (2014) builds on a multidisciplinary foundation that combines the research fields of architecture, anthropology, lighting engineering and media technology. Other studies, which have previously explored the use of VR systems as a tool for the design phase in architecture, although the diversity of the systems investigated is scarce, have largely found that the feedback provided by a VR system in regards to the spatial qualities of a design is unmatched by other design tools. A study by Angulo and de Velasco (2014) tested the use of VR to support students in the design of architectural spaces. They found that VR allowed the students to obtain aesthetic impressions of special design, and to test different design combinations of objects, while evaluating and validating the spatial geometrical relationships their designs conveyed. The feedback from such evaluation was shown to inform and promote changes in the design phase. Related findings regarding continuous feedback have also been previously shown (Achten & Turksma 1999; Smeltzer et al., 1994). Continuous feedback facilitates the evaluation of designs in 3D much faster than conventional methods (Achten & Turksma 1999) and with the added ability of real-time interaction to perform modifications to the design, enables the evaluation of design variations in a short time frame (Smeltzer et al., 1994), thereby increasing the productivity of the design process and allowing for more design iterations. Similarly, the ability to keep the height of the user in the VE at an eye height consistent with the user in the real world, together with using reference objects in the scene, enables the avoidance of the ambiguous or incorrect perception of scale in a VE (Kreutzberg, 2014; Tamke, 2005). These and other studies thus stress the importance of keeping the character in the VE at human height, as well as how intuitive navigation increases the level of immersion for the user (Kreutzberg, 2014; Angulo, A & de Velasco, 2014; Tamke, 2005). Studies also suggest that a VR design tool needs naturalistic elements in the interface (Dokonal et al., 2016), which can be achieved by using analogies from the real world combined with different functionalities and options within VR (Smeltzer et al., 1994). Studies have also stressed the importance and need for materials as well as shadows (Angulo, A & de Velasco, 2014; Coroado et al., 2015) since it helps with understanding complicated spaces and aids in the definition of volumes in the VE (Kreutzberg, 2014).

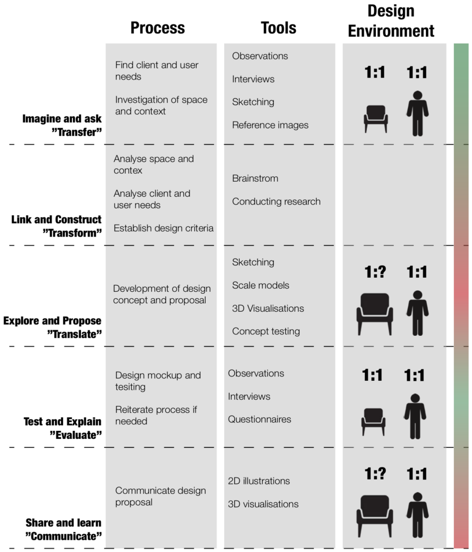

Figure 1
Process model of the example project.

The author has set out to develop a VR tool for application in lighting design with a departure point in these previous studies, with a particular emphasis on its use in design development (see Figure 1). The hypothesis is that the VR tool will improve upon the conventional process of today's lighting design practice. The author has furthermore defined three design criteria for its successful development: 1) Functionality, i.e. what the user is able to do with the tool; 2) Usability and interaction, i.e. how the user is able to interact with the tool; and lastly 3) Visual feedback, i.e. what the user is presented with visually.

METHOD

The development of the VR tool entailed the study of various game engines before deciding on Unity. Unity comes integrated with middleware for computing global illuminations (GI) called Enlighten. Enlighten directs the computing of indirect illumination and can achieve speeds that are considered close to real-time. For Enlighten to do so, it solves an approximation to the rendering equation for GI that assumes finite elements and a diffuse transport of light, thereby eliminating many variables in the GI equation to achieve real-time computational speed. This method for computing lighting (also known as Radiosity), though it does not offer physically accurate indirect illumination, gives an approximation at a fraction of the cost compared to other methods, thus making a VR lighting design tool feasible. At the time of development of this VR tool (early April 2018) there existed no method for calculating lighting in Unreal Engine 4, which was equivalent to Enlighten in Unity, whilst offering the same level of support and documentation from the developer, thus making Unity the more appropriate choice.

The VR lighting design tool in its current state of development offers the user the functionalities for selecting and instantiating different light fixtures from the projects asset folder, through the use of the "project" workspace. The lighting fixtures in the VE can then be moved into the required positions using the transformation gizmo. The translation of lighting fixtures is done through the use of EditorVR, an experimental asset package launched by Unity with an open API, as a tool for designers and creators to build VE's while being inside the VE itself. A custom tool enables access to the selected lights' properties, which makes it possible to change certain properties depending on the manufacturers' specification for that particular lighting fixture such as the lights color temperature, angular spread and lumen output. The VR lighting design tool takes full advantage of the benefits of VR by keeping the user immersed throughout the design process and ensures that the feedback in regards to both interaction and the visuals are real time.

After development, the initial hypothesis was tested through the collection and statistical analysis of data. Primarily, the collection of qualitative data was chosen to investigate if the VR tool improves upon the process of designing with light, how it does so, and what value the VR tool brings to the design process. The tests also collected quantitative usability data, which will be used to inform the future development of the VR lighting design tool. Since the tool is designed to be used in the lighting design process, the test participants were all lighting designers and the tool was tested in a design context similar to the one it has been designed to improve. The tests were thus structured as a scenario based usability test, where the participants were given an identical set of tasks to complete, using the VR tool's functionalities. Subsequently, interviews were conducted to collect responses on whether the VR tool brought any added value and benefit to the process of lighting design. The responses from the interview were analyzed using interpretive content analysis to find general themes in the participants' responses.

The test was conducted over a period of 5 days, from the 23rd to 27th of April near the Aalborg University campus in Copenhagen. For the hardware, An Oculus Rift with motion controllers and tracking sensors was used for the test, allowing the participants a tracking area of roughly 2 x 2m for navigating in the VE. The Oculus Rift guardian system was used to map out the tracking area and set up boundaries for the participant in the VE, in order to indicate if the participant was moving close to or outside the tracking area. The test was conducted on 18 participants (10 female, 8 male) between the age of 22 to 32 with 50% being between 24 and 25. All test participants were students from the Masters' program of lighting design from Aalborg University Copenhagen. The pre-test interview revealed that all participants had prior experiences with VR and were familiar with using 3D software in their lighting design process.

An interpretive content analysis was conducted on the responses from the post-test interview following the approach of emerging coding as described by Lazar, Feng, & Hocheiser (2017). The approach of emerging coding is based on the notion of grounded theory and is appropriate when theory and research literature on a subject is limited, which is true for the use of VR in the lighting design field.

RESULTS

The results from the interpretive content analysis indicate that the VR tool was believed applicable in both the design development process and the design communication process. For the purpose of design communication, participants wanted to use the VR tool to present walk-throughs of a space and to allow clients to take control of the VR tool with the ability to manipulate the light and the VE. Using VR to make walk-throughs of a space is no new feat within the AEC industry, but allowing for more interactivity in such process is an interesting topic that could be investigating further. How much control should be allowed to the client is unclear, but some participants believed that the client should only have the possibility to change properties in the VE that would be available after the implementation of the lighting design in the real world.

P11 (Q9) - "But for the client to use, it should be more simple, they should only be allowed to walk around, and not to change fixture properties, except in the real world if the fixtures come with some kind of user input".

Participants also mention that the VR tool could be used to mediate a discussion between the client and the designer (P18). Some participants believed that by allowing the client to use the tool, that it would be easier for them to experience different things (P9) and help them create a connection to the space (P18). Whether there would be more evidence to back up these claims is uncertain but it would be interesting to investigate further, to explore new ways for presenting lighting designs to clients and other parties.

Regarding the VR tools' applicability for design development, the responses showed a wide range of applications with the most frequent response being for the purposes of design experimentation. That this particular area (of design exploration) was the most frequent answer comes as no surprise, since the VR tool was presented to the participants as a tool for use following the initial concept development phase (see Figure 1), where in the authors' view it is most likely that some experimentation for the development of a concept will occur. Nevertheless, the responses are still considered reliable since a closer look suggests that a level of reflection took place before the participants answered the questions. From an analysis of the responses, it can be seen that some participants did not merely respond with a simple application for the VR tool but rather elaborated on their response, like participant 12:

P12 (Q6) - "It gave a nice overview of what the fixture would look like and gave a quick idea of how the lighting would look in the space".

Some participants also reflected on their use of the VR tool, comparing it to their previous experiences with lighting design development, like participants 2, 12 and 14.

P2 (Q8) - "it can sometimes be difficult to get a dimensional understanding of the room and what different fixtures would do to it, that is a thing that can be difficult to evaluate on a screen the effects of a light in the space, that was better here".

P12 (Q5) - "It is hard to sketch light, and here is it a better tool for sketching lighting".

P14 (Q8) - "sometimes when you go from sketching to Dialux it can be difficult to know what you get, this can be a good approximation".

When asked about what values, if any, the participant could see the tool bringing to their lighting design process, it seemed as though the benefits they had experienced would accommodate the problematic areas discovered in this project's analysis. The responses derived from the post-test interviews outline the values that VR in general would bring the lighting design process. These benefits include that VR can give the user a representation of light and space in 1:1 scale and from a human perspective, whilst giving a better understanding and impression of what differences lighting design can effect in spatial volumes. The VR tool was also believed to facilitate a better understanding, as well as save time, when communicating designs and to speed up the process of design development. By expediting the design development process more time could be used for testing different design possibilities, and thus more design iterations could be made, asserting more confidence in the design proposal.

The values highlighted above indicate that a VR tool could be able to overcome the problems regarding human spatial perception in the design development process imposed by the use of conventional design tools, thus adding value and improving the contemporary lighting design process. Though it is unclear how reliable the results are, due to the limitations imposed by how they were gathered, on who they were gathered and how they were analyzed, the results can at this stage can be considered to give a preliminary indication of the inherent values of a VR tool for the lighting design process, confirming previous studies relating to VR in architectural design.

With any new tool, it may be expected that some uncertainties and reservations about the tool will arise. In the case of this VR tool the reservations have especially been concerned with the amount of creativity the VR tool affords the user and what sort of context the VR tool can be used for.

The uncertainty of whether the VR tool would limit the users creativity has to be considered a major issue, since the VR tool is meant to be used for the design development, which is inherently a creative process. The concern about creativity is not a prominently featured area in the content analysis and the responses are either rather vague, P6 (Q12) - *"There could be some more playfulness with the creative aspects the user would be limited"*, or concern the lack of functionalities, like the responses from participant 11,12 and 13.

P11 (Q10) - "No, the program at its current stage would limit the user, so all the things above would need to be changed then it would be a tool that would be useful".

P12 (Q8) - "because you have total freedom when sketching. Do to the limited functionality it limited the capabilities for creativity".

P13 (Q8) - "It does, but the features are not complete and it does not have everything so it is limited creatively and not every fixture on the marked is available".

The functionalities that give ground to the concern for limiting design creativity are for participant 13 the variety of available fixtures that can be manipulated in the VE. Participant 11, when saying "all the things above", refers to difficulties with the controls. However, the variety and range of fixtures will expand with the further development of the VR tool whereas responses from other participant indicate that difficulties with the controls will diminish with continued use of the VR tool. As for the response from participant 12, it seams as though they are making a comparison of the creative aspects between sketching and the VR tool which indicates that the person might have misunderstood the intent of the VR tool. The VR tool is not meant to replace any conventional tool, and thus not designed to match any inherent functionalities from tools like sketching, but rather serve as a complimentary tool to the design development process. Since this response is the only one of its kind regarding this prospect of creativity, it has not been considered as representing a general view among the participant subjects.

Some concerns were expressed that questioned whether the VR tool would applicable in design contexts other than the relatively simple spatial environment tested in this project. While the initial goal for this VR tool was to improve the contemporary lighting design process, the tool ideally should be applicable in any lighting design context. Further testing in other virtual environments would however have to be conducted to establish this with any certainty.

The responses from the participants indicate that the VR tool in its current stage would not be applicable to develop designs for larger spaces. This is due to the uncomfortable ways of navigating the VE (P11) and because it is believed the VR tool would lose its immersive feeling if the space was much larger (P9).

P9 (Q10) - "If the project was a simple room and there was a bigger selection of fixtures then yes, if the room was much bigger the tool would use its immersive feeling".

P11 (Q6) - "When the room is so small you do not really need to walk around, but if the room was bigger navigation could become a problem".

The capabilities of VR is not believed to be a limiting factor when it comes to generalizing the applicability of this VR tool. The dimensions and scales of objects follow a 1:1 relationship with the real world and give a sense of dimensionality to a space unmatched by any other conventional design tool. As expressed by participant 8 - *"you can get something that is closer to reality compared to what other tools can give you at the moment"*. The VR tool builds on the same principles and one can thus assume that if the issues with the navigation were resolved, that the applicability of the VR tool could be extended to other project contexts.

CONCLUSION

While the project's results are limited due to its proof-of-concept development stage, the responses from the participants indicate that the tool is advantageous in the design development as well as the design communication phases. Results indicate that the VR tool can speed up the process of design experimentation allowing for more design iterations and experiments; that they could perceive spatial lighting effects better than with conventional design tools; and that the tool allowed a better representation of the space and lighting at a 1:1 scale from a human perceptual perspective giving the lighting designer an opportunity to become an actor in the space rather than an observer behind a screen.

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